Rheological Properties of Quasi-2D Fluids in Microgravity

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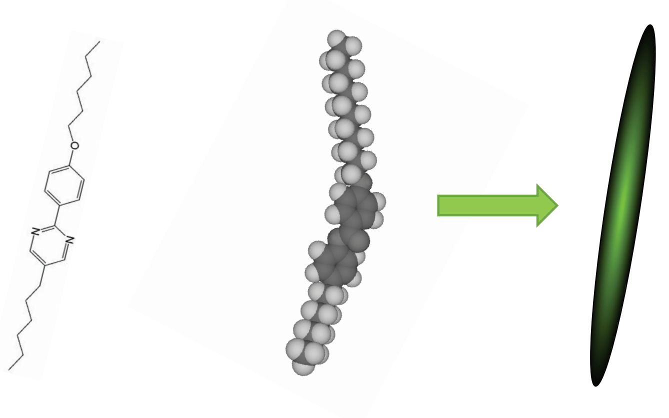
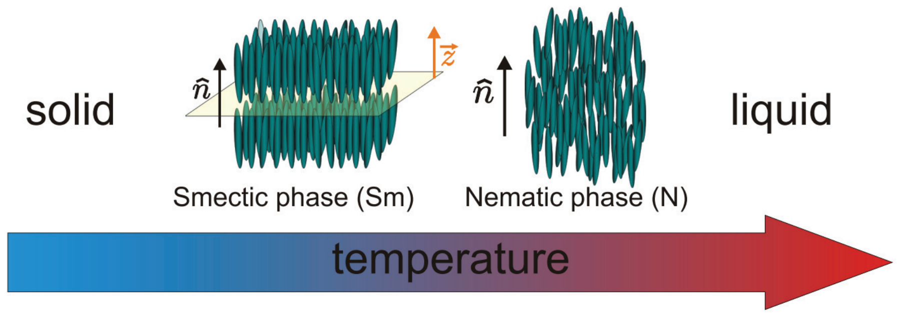
Liquid Crystals

- Liquid crystals (LCs) are anisotropic liquids,
- They possess the fluidity of a true liquid, as well as varying degrees of long-range orientational and positional order that are normally associated with crystalline solids



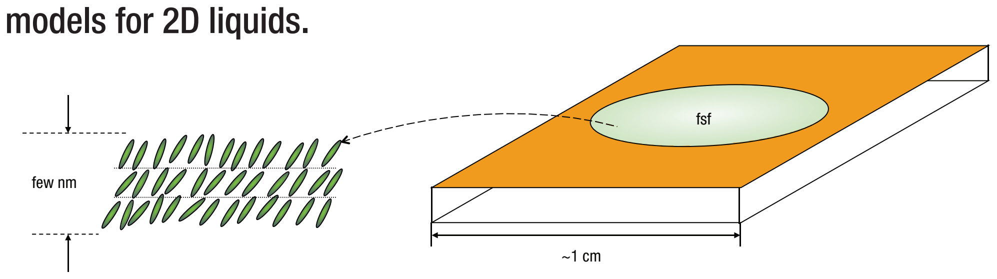
Structure and model of a liquid crystal molecule

Some Thermotropic LC-Phases



Science Background

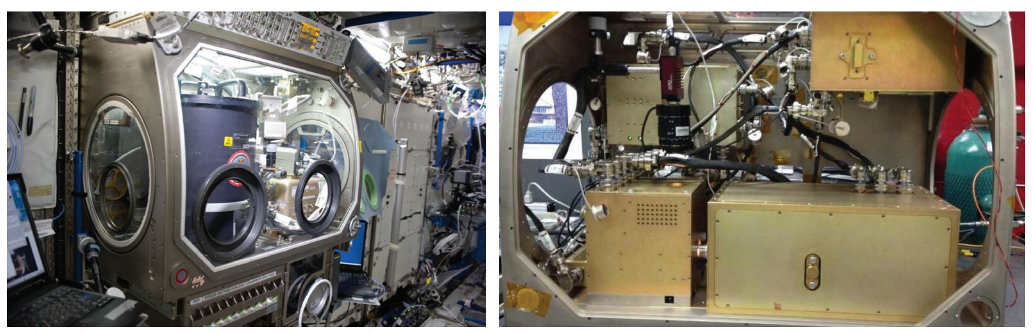
The smectic layer structure facilitates the preparation of freely suspended films with thicknesses of few molecular layers. With lateral extensions up to several cm, aspect ratios can exceed 10^6. Such films may serve as models for 2D liquids.



Schematic sketch of a setup for the preparation of freely suspended smectic films.

The OASIS Experiment on the International Space Station (ISS)

Sample modules with smectic bubbles are imaged in the OASIS experiment chamber. The setup makes use of the Microgravity Science Glovebox aboard the ISS.



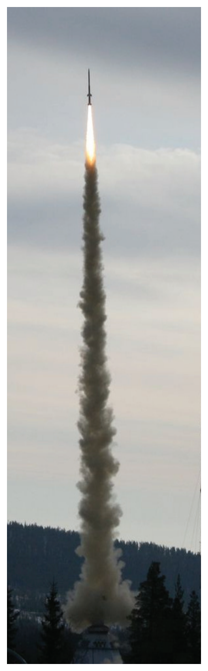
Microgravity Science Glovebox (left) and OASIS specific hardware (right).

OASIS Objectives

- Exploitation of the unique characteristics of freely suspended liquid-crystal films in a microgravity environment, to advance the understanding of fluid state physics.
- Microgravity suppresses the sedimentation of objects on the films, this allows long time observations of droplets or smectic islands on LC bubbles.

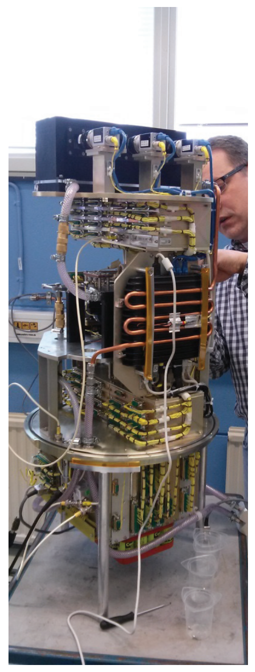
TEXUS Suborbital Flight

The OASIS-Tex project was scheduled as a parameter test for OASIS. It provided experimental data on the Marangoni instability in smectic films.



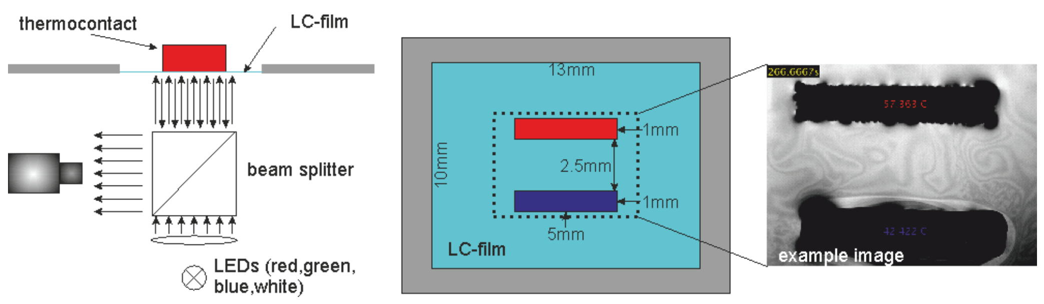
TEXUS-52 (left) with the OASIS-Tex setup started successfully in Esrange (Sweden) on April 27, 2015, and reached a height of 250 km providing 6.5 minutes of microgravity (µg). The experiment (right) was built and tested in cooperation with German Space Agency (DLR) and Astrium.

DLR Deutsches Zentrum für Luft- und Raumfahrt



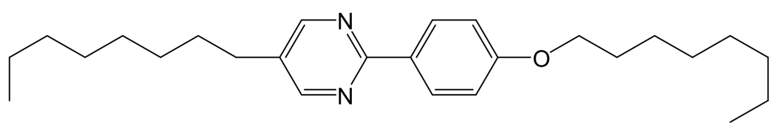
The OASIS-Tex Experiment

- Freely suspended smectic film with thermocontacts



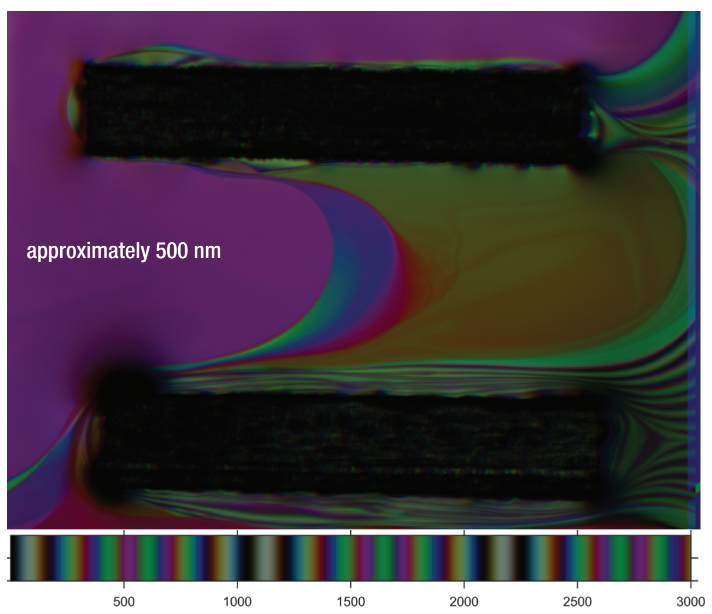
Schematic side view (left) and top view (middle) of the OASIS Marangoni setup. Two thermocontacts are placed on a free-standing smectic film. Convection is seen by the Schlieren texture of the smectic c director field. The camera shows an 7mm x 5mm section of the film plane (right).

- LC: 5-n-Octyl-2-(4-n-octyloxyphenyl)pyrimidine



Cr 28.5 SC 55.5 SA 62 N 68 I

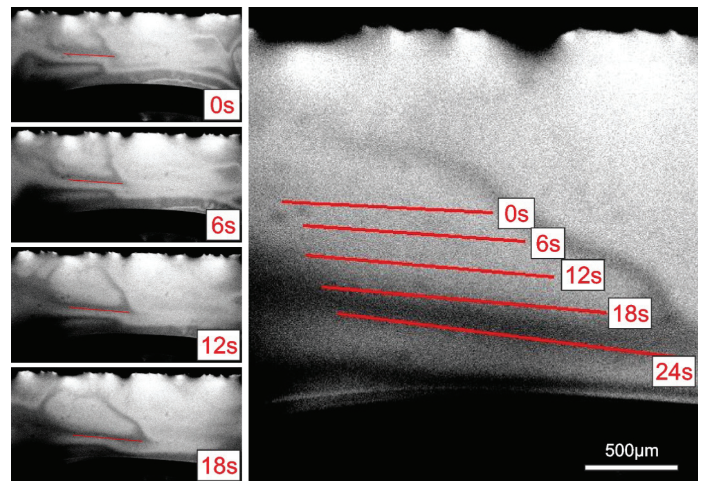
- Ambient temperature 50 °C
- Thermogradient up to 10 K/mm
- LC film thickness is approximately 500 nm



The film thickness was determined from reflectivity of the three different RGB-LEDs in the early stage of the experiment. During the experiment the marked 500 nm thick homogeneous part spreads over the whole film.

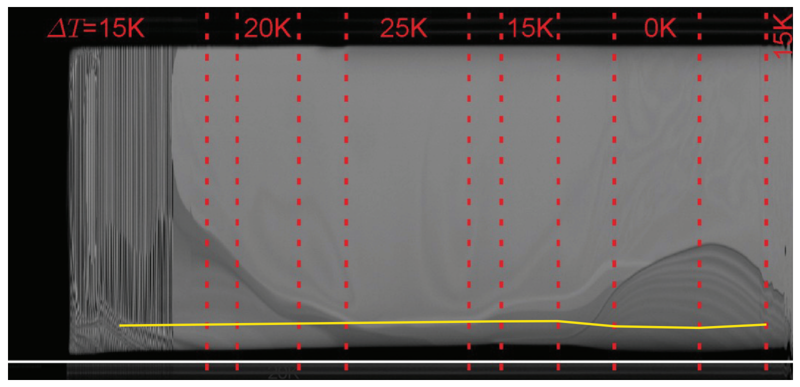
OASIS-Tex Results

- For temperature gradients $\Delta T < 9.6$ K/mm we observe a drift in the film from the warm towards the cold contact.



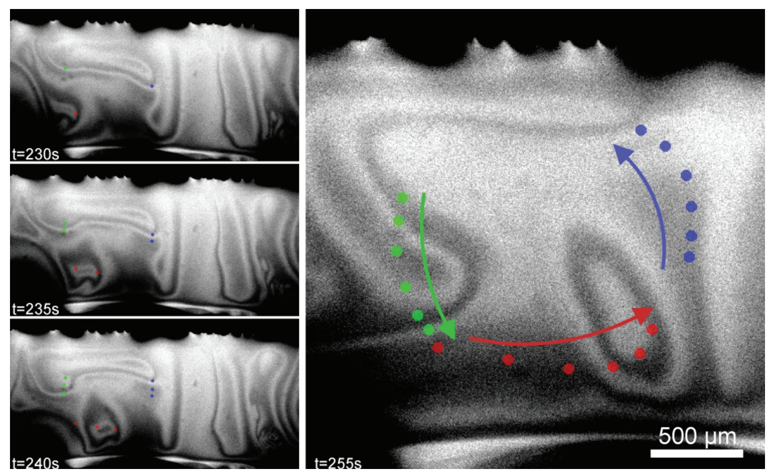
Images show the motion of a texture front from the warm towards the cold contact. The red lines indicate the moving front. The temperature gradient is slightly below 8 K/mm.

- Velocity ($\Delta T < 8$ K/mm) is approximately 25 µm/s.
- Velocity ($\Delta T > 8.8$ K/mm) is approximately 70 µm/s



Space-time plot of the experimental situation. Each vertical line represents the same vertical line between the two contacts out of the original images. The timeline is from left to right.

- Smectic material collects at the cold contact.
- Removal of the gradient leads to remigration of material into the film from the former cold contact.



Images show the motion of a texture between the two tempered thermocontacts. A convection roll is visible. The temperature gradient is about 10 K/mm.

- Onset of convective motion at $\Delta T > 9.6$ K/mm.
- Textures move with a velocity of ~30 µm/s.

Conclusions

- We observe a practically thresholdless Marangoni flow, with hot material replacing cold film material, even in small thermal gradients,
- Only in large thermal gradients (~10 K/mm) we find a convective instability.
- Previous observations under normal gravity [Godfrey and van Winkle, *Phys. Rev. E* **54**, 3752 (1996)] can be explained by meniscus-driven thermal convection.